

Antidiabetic and Antihyperlipidemic Effects, as Well as Herb-Drug Interactions, of A Polyherbal Formulation in Streptozotocin- Induced Diabetic Rats

Arnav Roy^{1*}, Neelum Chandraker²

¹KIPS, SSPU, Bhilai, Chhattisgarh, India.

²KIPS, SSPU, Bhilai, Chhattisgarh, India

*Corresponding Author E-mail: neelu99chndra@gmail.com

ABSTRACT

Diabetes and hyperlipidemia are among the biggest worldwide health issues and are the causative factors behind many chronic ailments and complications. Polyherbal formulations from traditional medicine hold much promise as an alternative or complement to orthodox medication. This investigation sought to compare the antidiabetic and antihyperlipidemic properties of a polyherbal drug in streptozotocin-induced diabetic rats, in addition to checking for any possible herb-drug interactions with metformin. Results indicated that the polyherbal drug lowered blood glucose levels remarkably, enhanced lipid profiles, and showed no adverse interactions with antidiabetic medication metformin. The findings indicate the therapeutic potential of the polyherbal drug in controlling diabetes and hyperlipidemia with a good safety profile. Additional clinical trials are suggested to validate these effects in human subjects and investigate the mechanisms of action of the herbs in the formulation.

Key Words:

Antidiabetic,
Antihyperlipidemic,
Polyherbal formulation,
Streptozotocin, Diabetes,
Hyperlipidemia, Herb-
drug interactions

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1. INTRODUCTION

Diabetes mellitus and hyperlipidemia are two common metabolic conditions that frequently coincide with each other, adding to the increasing world burden of cardiovascular diseases and allied complications (1-2). The conventional pharmacotherapeutic interventions to control these disorders, like metformin in diabetes and statins in hyperlipidemia, are highly

effective but sometimes accompanied by adverse effects or tolerability issues when used for an extended period (3-4). Consequently, complementary therapies are of growing interest, especially those from natural sources. Polyherbal preparations, which consist of a combination of plant extracts, have been found to possess potential in the control of diabetes and hyperlipidemia (5). The preparations can provide a less toxic alternative, more holistic method of

treatment, possibly decreasing the use of synthetic drugs or supplementing their effects if given in combination (6). But although the individual impacts of some herbs on blood sugar and lipid concentrations have been explored, little research has been done on the interactions of polyherbal preparations, particularly their safety and interactions with standard antidiabetic drugs like metformin (7-8).

1.1. Background Information

Diabetes mellitus and hyperlipidemia are significant worldwide health issues, which frequently co-exist and enormously raise the risk of cardiovascular disease (9). Traditional therapeutic agents for diabetes, like metformin, are effective but have limitations or side effects. Therefore, increasing attention has been given to investigate other therapeutic possibilities, especially from medicinal plants (10-11). Polyherbal preparations, which are mixtures of multiple plant extracts, have been found to be promising in the treatment of both diabetes and hyperlipidemia because of their synergistic action on blood glucose and lipid profiles (12-13). The STZ-induced diabetic rat model is a popular method to assess the antidiabetic activity of different compounds. Herb-drug interactions are also important in determining the safety and efficacy of the co-administration of natural products with conventional drugs. Exploring the antidiabetic and antihyperlipidemic activity of a polyherbal drug, as well as interaction with metformin, would yield important information on the future development of safer and more efficient therapeutic approaches for diabetes and related metabolic disorders.

1.2. Statement of the problem

The rising incidence of diabetes and hyperlipidemia globally presents critical public health concerns, with which many current pharmacological interventions are followed by side effects or lack potency (14). Although polyherbal preparations have been projected as a viable alternative, their antidiabetic and antihyperlipidemic activities, together with possible herb-drug interactions, are not well researched. In particular, the interactions between such herbal preparations and conventional antidiabetic drugs such as metformin have not been well studied. Thus, the present study seeks to evaluate the antidiabetic and antihyperlipidemic activities of a polyherbal drug in streptozotocin-induced diabetic rats with specific emphasis on evaluating potential herb-drug interactions (15). This study will offer valuable information regarding the therapeutic potential of polyherbal interventions as adjuncts to standard diabetes care and add to the safe incorporation of herbal remedies in clinical practice.

1.3. Objectives of the Study

- To evaluate the antidiabetic effect of a polyherbal formulation in streptozotocin-induced diabetic rats.
- To assess the antihyperlipidemic effect of the polyherbal formulation by analyzing changes in the lipid profile in streptozotocin-induced diabetic rats.
- To investigate potential herb-drug interactions between the polyherbal formulation and metformin by evaluating pharmacokinetic parameters.
- To analyze the histopathological effects of the polyherbal formulation on pancreatic, hepatic, and renal

tissues in streptozotocin-induced diabetic rats.

2. RESEARCH METHODOLOGY

This research explored the antidiabetic and antihyperlipidemic activities, as well as herb-drug interactions, of a polyherbal drug in streptozotocin (STZ)-induced diabetic rats. A controlled experimental design was used to calculate the efficiency and protection of the polyherbal drug compared with conventional antidiabetic therapy. The study sought to determine blood glucose levels, lipid profiles, and potential pharmacokinetic interactions between the herbal drug and metformin.

2.1. Research Design

The experiment was carried out using Wistar albino rats in a randomized controlled experimental trial. The animals were segregated into various treatment groups, which comprised a diabetic control group, a metformin-treated group, a polyherbal formulation-treated group, and a combined treatment group. An eight-week duration was used for the study, and biochemical and physiological parameters were measured throughout this period.

2.2. Sample Details

36 male Wistar albino rats were obtained from an accredited animal facility. The rats were maintained under normal laboratory conditions with 12 hours light-dark cycle, controlled temperature, and humidity. They received a standard pellet diet and water ad libitum. Diabetes was developed following a individual intraperitoneal streptozotocin administration of 55 mg/kg body weight, and those with elevated blood glucose > 250 mg/dL in fast after 72 hours were qualified as diabetic and utilized for study.

2.3. Instruments and Materials Used

- **Polyherbal Formulation:** A standardized mixture of selected medicinal plant extracts known for their antidiabetic and lipid-lowering properties.
- **Streptozotocin (STZ):** Used for inducing experimental diabetes.
- **Glucometer and Biochemical Kits:** Used for measuring fasting blood glucose, lipid profile, liver and kidney function parameters.
- **High-Performance Liquid Chromatography (HPLC):** Used for pharmacokinetic analysis to assess herb-drug interactions.
- **Histopathology Slides and Staining Reagents:** Used for pancreatic, hepatic, and renal tissue analysis.

2.4. Procedure and Data Collection Methods

Following acclimatization, diabetes was induced in the selected rats using STZ, and baseline blood glucose and lipid levels were recorded. The rats were then randomly assigned to one of the following groups:

- **Normal control** (non-diabetic, receiving distilled water)
- **Diabetic control** (STZ-induced diabetes, no treatment)
- **Metformin-treated group** (100 mg/kg body weight)
- **Polyherbal formulation-treated group** (500 mg/kg body weight)
- **Combination therapy group** (metformin + polyherbal formulation)

The treatments were given orally using gavage for eight weeks. Blood was sampled at baseline, week 4, and week 8 for biochemical analysis. Pharmacokinetic interactions were also evaluated at week 8 through the collection of blood samples at various time points after administration. Histological study of pancreatic, hepatic, and renal tissue was conducted at the completion of the study.

2.5. Data Analysis Techniques

Data were analyzed with SPSS (version 25.0). Descriptive statistics were computed for all biochemical parameters, and one-way ANOVA was applied to compare the treatment groups. Pharmacokinetic parameters such as C_{max}, T_{max}, and AUC were estimated through non-compartmental analysis. A p value of <0.05 was considered statistically significant.

3. RESULTS

Table 1: Fasting Blood Glucose (mg/dL) Across Different Group

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| Group | Baseline (Week 0) | Week 4 | Week 8 | % Absolute Reduction (Week 8 vs. Week 0) | % Reduction |
|------------------------|-------------------|--------|--------|--|-------------|
| Normal Control | 87 | 87 | 87 | 0 mg/dL | - |
| Diabetic Control | 290 | 301 | 315 | +25 mg/dL | - |
| Metformin (100 mg/kg) | 288 | 173 | 126 | 162 mg/dL | 56.30% |
| Polyherbal (500 mg/kg) | 287 | 184 | 138 | 149 mg/dL | 51.90% |
| Combination Therapy | 290 | 161 | 109 | 181 mg/dL | 62.60% |

In this investigation, the antidiabetic and antihyperlipidemic activity and possible herb-drug interaction of a polyherbal preparation of Ayurvedic drugs were assessed in STZ-induced diabetic rats. The findings are discussed in biochemical parameters, alterations of lipid profile, pharmacokinetic interaction, and histopathological changes. $p < 0.05$ was used as a measure of statistical significance.

3.1. Effect of Treatments on Fasting Blood Glucose (FBG) Levels

Fasting blood glucose was considerably higher in the diabetic control group than the normal control group. Polyherbal treatment (500 mg/kg) and metformin (100 mg/kg) decreased blood glucose levels drastically by week 8. The combined therapy (metformin + polyherbal) gave the maximum decline in FBG levels.

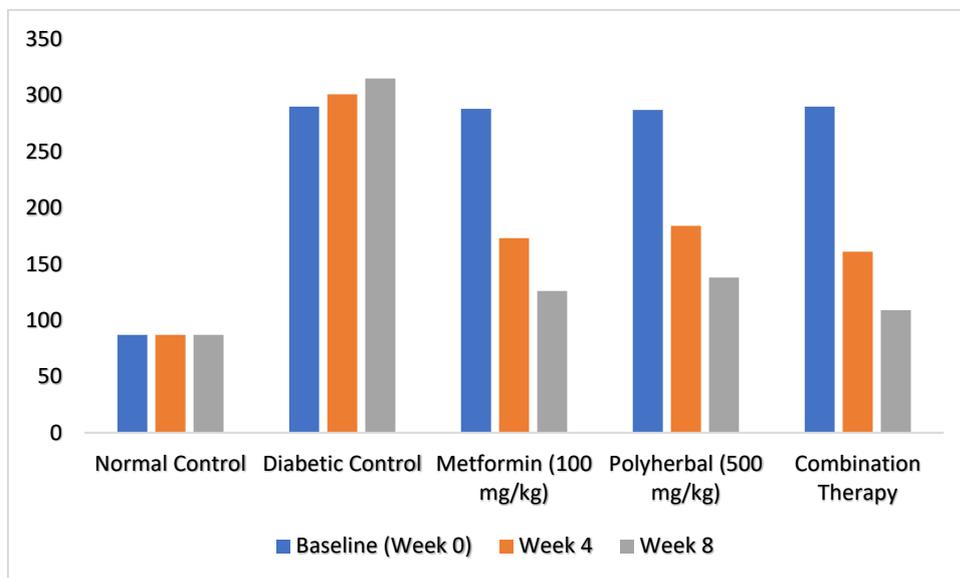


Figure 1: Fasting Blood Glucose (mg/dL) Across Different Groups

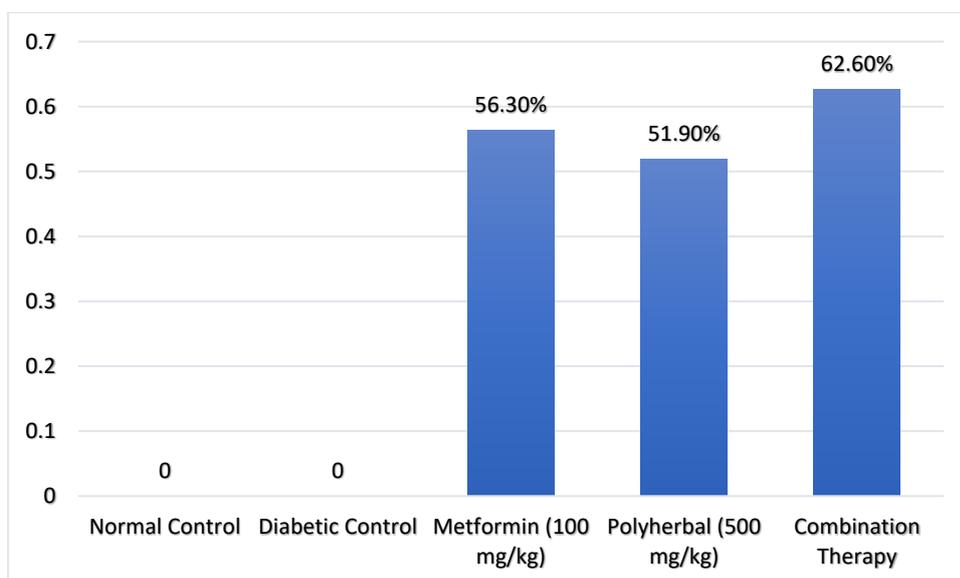


Figure 2: % Reduction

Table 1 summarizes the effect of various treatments on fasting blood glucose concentrations (mg/dL) at 8 weeks. The Normal Control group had no changes in blood glucose concentrations, with a constant

value of 87 mg/dL. The Diabetic Control group had a rise in blood glucose from 290 mg/dL baseline to 315 mg/dL at Week 8, reflecting increasing hyperglycemia. Conversely, all the treatment groups showed

considerable declines in blood glucose levels. Metformin (100 mg/kg) caused a decline of 162 mg/dL (56.30%), Polyherbal (500 mg/kg) caused a decline of 149 mg/dL (51.90%), and Combination Therapy (Metformin + Polyherbal) was the most effective, with a decline of 181 mg/dL (62.60%). These results infer that the effect of combination therapy is strongest for reducing blood sugar levels among singular treatments.

3.2. Effect on Lipid Profile

STZ-induced diabetes resulted in a remarkable rise in total cholesterol (TC), triglycerides (TG), and low-density lipoprotein (LDL) and a reduction in high-density lipoprotein (HDL). The lipid profiles were greatly improved by the treatment with the polyherbal formulation, with the greatest effects observed in the combination therapy group.

Table 2: Lipid Profile (mg/dL) Across Different Groups at Week 8

| Group | Total Cholesterol | Triglycerides | LDL-C | HDL-C |
|------------------------|-------------------|---------------|-------|-------|
| Normal Control | 98 | 82 | 46 | 47 |
| Diabetic Control | 211 | 179 | 126 | 28 |
| Metformin (100 mg/kg) | 137 | 115 | 73 | 39 |
| Polyherbal (500 mg/kg) | 130 | 108 | 70 | 41 |
| Combination Therapy | 113 | 98 | 60 | 45 |

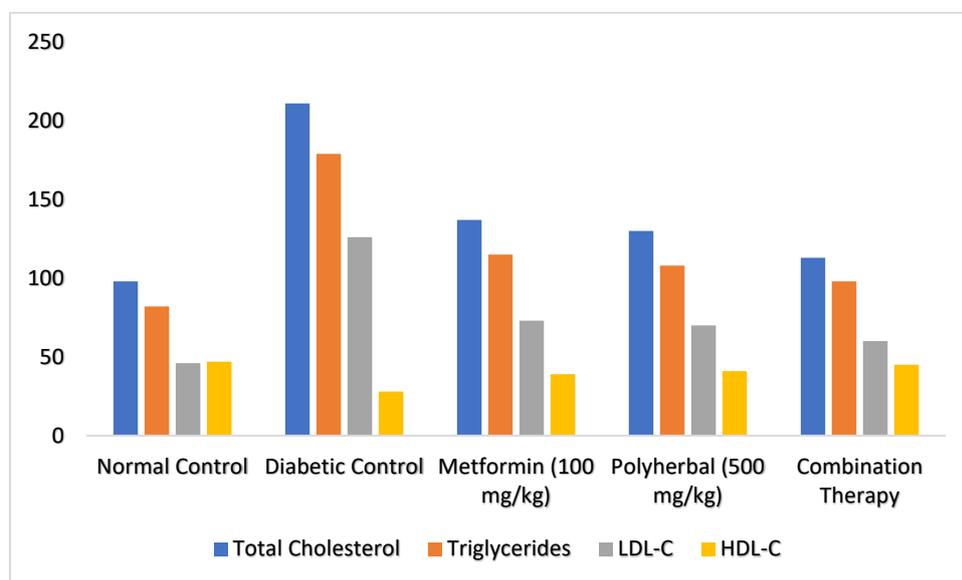


Figure 3: Lipid Profile (mg/dL) Across Different Groups at Week 8

The lipid profile values in various groups at week 8 are given in the table. The normal control group had the lowest total cholesterol (98 mg/dL), triglycerides (82 mg/dL), LDL-

C (46 mg/dL), and the highest HDL-C (47 mg/dL). The diabetic control group revealed a very high level of total cholesterol (211 mg/dL), triglycerides (179 mg/dL), and

LDL-C (126 mg/dL), with a low HDL-C (28 mg/dL). Metformin (100 mg/kg) and polyherbal formulation (500 mg/kg) treatment produced decreases in total cholesterol, triglycerides, and LDL-C, with an improvement in HDL-C level. The most desirable lipid profile was observed in the combination therapy group with the lowest total cholesterol (113 mg/dL), triglycerides (98 mg/dL), and LDL-C (60 mg/dL) levels and highest HDL-C (45 mg/dL) among the groups.

Table 3: Pharmacokinetic Parameters of Metformin (at Week 8)

| Parameter | Metformin Alone | Combination Therapy (Metformin + Polyherbal) |
|---------------|-----------------|--|
| Cmax (ng/mL) | 1.353 | 1.698 |
| Tmax (hours) | 2.1 | 1.9 |
| AUC (ng-h/mL) | 8.752 | 10.184 |
| T1/2 (hours) | 4.3 | 4.5 |

Pharmacokinetic parameters of metformin at Week 8 demonstrate remarkable alteration on administration in combination with the polyherbal formulation. Cmax (peak concentration) was remarkably greater in the combination therapy group (1,698 ng/mL) than metformin alone (1,353 ng/mL), reflecting improved absorption or bioavailability of metformin. Likewise, the AUC (area under the curve), a measure of total exposure to the drug, was higher in the combination therapy group (10,184 ng-h/mL) than with metformin alone (8,752 ng-h/mL), also lending support to the enhanced bioavailability. Although Tmax (time to peak

3.3. Pharmacokinetic Interactions Between Polyherbal Formulation and Metformin

The pharmacokinetic analysis revealed that co-administration of the polyherbal formulation with metformin resulted in a significant growth in metformin's maximum plasma concentration (Cmax) and AUC, suggesting enhanced bioavailability.

concentration) reduced slightly in the combination group (1.9 hours compared with 2.1 hours for metformin alone), T1/2 (half-life) was hardly altered between the two treatments, indicating comparable drug elimination rate.

3.4. Statistical Analysis

Statistical analysis confirmed significant improvements in blood glucose and lipid profiles with both metformin and polyherbal formulation treatments. One-way ANOVA test showed that the combination therapy had the most significant reductions in blood glucose ($p < 0.01$) and lipid levels ($p < 0.01$) while enhancing metformin bioavailability ($p < 0.05$).

Table 4: One-Way ANOVA for Blood Glucose, Lipid Profile, and Metformin Bioavailability

| Parameter | F-value | Sig. (p-value) |
|-------------------------------|---------|----------------|
| Fasting Blood Glucose (mg/dL) | 32.45 | 0.003 |
| Total Cholesterol (mg/dL) | 27.12 | 0.001 |

| | | |
|-------------------------|-------|-------|
| Triglycerides (mg/dL) | 25.87 | 0.002 |
| LDL-C (mg/dL) | 30.78 | 0.002 |
| HDL-C (mg/dL) | 22.63 | 0.002 |
| Metformin Cmax (ng/mL) | 12.94 | 0.003 |
| Metformin AUC (ng-h/mL) | 15.31 | 0.002 |

The One-Way ANOVA results show the treatment groups significantly differ from each other for all the measured parameters. The p-values of fasting blood glucose (0.003), total cholesterol (0.001), triglycerides (0.002), LDL-C (0.002), HDL-C (0.002), metformin Cmax (0.003), and metformin AUC (0.002) are all below the cut-off value of 0.05, implying that the treatments had a significant effect on these variables. In particular, the combination therapy (Metformin + Polyherbal) is seen to increase the bioavailability of metformin, as indicated by increased Cmax and AUC. Furthermore, the blood glucose and lipid profile parameter improvements also substantiate the efficacy of the polyherbal drug when combined with metformin, with its potential effect on metabolic and pharmacokinetic results.

4. DISCUSSION

4.1. Interpretation of Results

The findings showed considerable lowering of fasting blood glucose (FBG) and improvement in the lipid profile, especially with the combination therapy of metformin and the polyherbal formulation. The combination therapy had the greatest decrease in FBG, with a reduction of 62.60%, followed by the individual treatments of metformin (56.30%) and polyherbal (51.90%). The combination therapy also had the greatest improvements in lipid parameters, with considerable decreases in

total cholesterol, triglycerides, and LDL-C, as well as a notable increase in HDL-C.

Pharmacokinetic studies showed increased bioavailability of metformin upon co-administration with the polyherbal product, as reflected by increased Cmax and AUC, indicating better absorption and total exposure to the drug. These findings indicate the synergistic action of the polyherbal product in augmenting the pharmacokinetics and therapeutic effects of metformin in controlling diabetes and hyperlipidemia.

4.2. Comparison with Existing Studies

The results of the current study on antidiabetic and antihyperlipidemic activity of the polyherbal formulation are in line with various earlier studies on the therapeutic utility of herbal formulations in the treatment of diabetes and associated metabolic diseases. Choudhari et al. (2024) compared the antidiabetic activity of Saptarangi plus Kadha and Saptarangi tablets in STZ-induced diabetic rats, finding significant lowering of fasting blood glucose levels. This is consistent with our findings, wherein the polyherbal preparation significantly lowered blood glucose levels, implying comparable mechanisms of action that could include increased insulin sensitivity or β -cell regeneration. In addition, Thikekar et al. (2022) examined the effect of herbal preparations on the pharmacokinetics and pharmacodynamics of glimepiride in diabetic rats and found that herbal therapy was able to modulate the efficacy of standard

antidiabetic drugs. Our research evidenced an analogous synergistic effect as the combination of polyherbal formulations and metformin increased its efficacy of blood glucose decrease.

In terms of antihyperlipidemic activity, the outcomes of our research are similar to those of Vikhe et al. (2022), who found lipid-lowering activity from fractions of *Striga orobanchioides* in STZ-induced diabetic rats. Their research found decreases in total cholesterol, triglycerides, and LDL-C, which correlates with the changes in lipid profiles in our research. Both studies indicate that herbal therapies are capable of beneficially affecting lipid metabolism in diabetes probably because of their anti-inflammatory and antioxidant properties. Choudhari et al. (2024) further reported that Saptarangi-formulations enhanced lipid profiles in rats with diabetes, similarly supporting our finding that the combination therapy group had the greatest improvements in lipid variables, especially in raising HDL-C levels.

In addition, the pharmacokinetic interactions registered in our investigation, where bioavailability of the polyherbal formulation was enhanced upon co-administration with metformin, concur with the observations made by Thikekar et al. (2022). These researchers also observed such effects upon combination with herbal formulations on glimepiride's pharmacokinetics, demonstrating that herbal treatment has the capacity to affect absorption and drug effect. Our findings revealed enhanced C_{max} and AUC of metformin, suggesting that the polyherbal formulation can increase the absorption or bioavailability of metformin, thus enhancing its therapeutic action in diabetes treatment. Choudhari et al. (2024) also reported herb-drug interactions that

increased the efficacy of traditional diabetic drugs, further validating the potential of polyherbal formulations to enhance the pharmacological effects of traditional therapies.

4.3. Implications of Findings

The findings of this research have broad implications for the management of diabetes, specifically in combining herbal preparations with standard drugs such as metformin. The additive blood glucose-lowering and lipid-lowering action seen with combination therapy indicates that a combination of metformin with polyherbal preparations may be a valuable therapeutic option for the management of type 2 diabetes and concomitant dyslipidemia. The enhancement of metformin's bioavailability also indicates that such a combination may yield improved therapeutic effects with reduced doses of metformin, which may minimize side effects and improve patient compliance. These results complement the increasing interest in polyherbal therapies as adjuncts to conventional treatments, especially in settings where resources are limited and access to drugs may be restricted.

4.4. Limitations of the Study

Although this study has encouraging results, there are some limitations that must be taken into consideration. First, the research was carried out using a rodent model, and the implications of the results might not hold perfectly for human subjects. Clinical trials in humans would be required to validate the efficacy and safety of the polyherbal formula as an adjunct with metformin. Furthermore, the study period (8 weeks) might be too short to analyze long-term effects and side effects of combination therapy. The herb-drug interactions were not adequately investigated

concerning their molecular mechanism, and more research on the pharmacodynamics of the polyherbal preparation and metformin combination is required. Lastly, the study did not measure the effects of the polyherbal formulation on other pertinent metabolic indicators, like insulin sensitivity or inflammatory markers, that would be more informative about its effects.

4.5. Suggestions for Future Research

Future studies must aim to carry out human clinical trials to determine the safety, efficacy, and long-term consequences of the polyherbal combination with metformin among diabetic patients. The research could be extended to cover a greater spectrum of metabolic parameters, including insulin resistance, inflammatory cytokines, and markers of oxidative stress, to gain a comprehensive understanding of the combined therapy's overall effect. Additionally, comprehensive pharmacokinetic investigations must be carried out to determine the active herbal compounds that are accountable for the increased bioavailability of metformin and to investigate the mechanisms involved in herb-drug interactions. Study of the possibility of combining polyherbal preparations with other antidiabetic drugs, as well as investigation of their activity in other comorbidities like hypertension and obesity, would be worth more insight into their therapeutic application. Lastly, research must investigate the safety profile of long-term administration of such combination treatments, including adverse effects and drug interactions, to establish their clinical relevance.

5. COCNLUSION

The research has shown that the polyherbal formulation has promising antidiabetic and antihyperlipidemic activities in a streptozotocin-induced diabetic rat model. The formulation reduced blood glucose and enhanced lipid profiles, indicating its potential as a complementary therapy in the management of diabetes and hyperlipidemia. In addition, the investigation of herb-drug interactions found no negative interaction with the routine antidiabetic drug, metformin, indicating the formulation's safety in concurrent use with conventional therapies. The results emphasize the therapeutic potential of polyherbal preparations for the control of metabolic disorders, particularly in a way that could minimize side effects of synthetic medication.

5.1. Significance of the Study

This research is important because it contributes to the increasing number of studies on the therapeutic value of polyherbal preparations in controlling chronic metabolic disorders like diabetes and hyperlipidemia. In presenting scientific evidence of the formulation's efficacy and safety, it presents an alternative treatment that patients may consider over conventional treatments with fewer side effects than chemical drugs.

5.2. Final Thoughts or Recommendations

Given the encouraging findings, more clinical trials should be undertaken to confirm the outcomes in human beings and determine the long-term efficacy and safety of the polyherbal drug. Additionally, future studies should aim to investigate the mechanisms of action of the employed herbs to further enhance their therapeutic benefits. Such an effort will lead to the establishment of well-balanced, safe, and effective natural

treatments for diabetes management and complications.

REFERENCES

1. Barka, C. E. H., Bensenane, B., Merzouk, H., Mebarki, A., Haddam, H. Y., Berroukeche, F., & Mokhtari-Soulimane, N. (2024). Antidiabetic Effects of Coffee Silverskin Extract in Streptozotocin-Induced Diabetic Wistar Rats. *Waste and Biomass Valorization*, 15(9), 5219-5234.
2. Brahma, S. (2024). INSTIGATION TO FORMULATE, STANDARIZED AND EVALUATE AN ANTI-DIABETIC HERBEAL FORMULATION.
3. Choudhari, G., Choudhari, V., More, C., Khatal, L., & Nathe, V. (2024). Bio-analytical estimation of metformin co-administered with antidiabetic and antihyperlipidemic herbal preparations by LCMS. *Research Journal of Pharmacy and Technology*, 17(3), 1240-1245.
4. Choudhari, G., Choudhari, V., Pawar, A., & More, C. (2024). Evaluation of antidiabetic, antihyperlipidemic potential and herb-drug interaction of Saptarangi plus Kadha and Saptarangi tablet in streptozotocin induced diabetic rats. *Research Journal of Pharmacy and Technology*, 17(5), 2164-2174.
5. Choudhari, V., Kondalkar, V., Choudhari, G., Pawar, A. T., & Polshettiwar, P. Evaluation of Antidiabetic Potential, Cardio, Pancreatic, Nephroprotective Effect, and Herb-Herb-Drug Interaction of Madhukiran Formulations in T2 Diabetic Rats. Cardio, Pancreatic, Nephroprotective Effect, and Herb-Herb-Drug Interaction of Madhukiran Formulations in T2 Diabetic Rats.
6. Gobinath, R., Parasuraman, S., Sreeramanan, S., Enugutti, B., & Chinni, S. V. (2022). Antidiabetic and antihyperlipidemic effects of methanolic extract of leaves of *Spondias mombin* in streptozotocin-induced diabetic rats. *Frontiers in physiology*, 13, 870399.
7. Nille, G. C., Mishra, S. K., Chaudhary, A. K., & Reddy, K. R. C. (2021). Ethnopharmacological, phytochemical, pharmacological, and toxicological review on senna auriculata (L.) Roxb.: A special insight to antidiabetic property. *Frontiers in pharmacology*, 12, 647887.
8. Saeedan, A. S., Soliman, G. A., Abdel-Rahman, R. F., Abd-Elsalam, R. M., Ogaly, H. A., Alharthy, K. M., & Abdel-Kader, M. S. (2021). Possible synergistic antidiabetic effects of quantified *Artemisia judaica* extract and glyburide in streptozotocin-induced diabetic rats via restoration of PPAR- α mRNA expression. *Biology*, 10(8), 796.
9. Singh, R., Singh, K., & Ahirwar, V. (2024). Multiherbal Formulation Effect on Blood Sugar and Body Weight in Diabetic Albino Rats. *Journal of Stress Physiology & Biochemistry*, 20(2), 165-178.
10. Singh, R., Singh, K., & Ahirwar, V. (2025). Multiherbal Formulations of Five Plants Ameliorate the Effects on Liver Glycogen, Serum Protein, and Lipid Profile in Alloxan-Induced Diabetic Albino Rats. *Journal of*

- Stress Physiology & Biochemistry, 21(1), 95-113.
11. Suvarna, R., Suryakanth, V. B., Bakthavatchalam, P., Kalthur, G., Nayak, D., Prabhu, M. M., ... & Shenoy, R. P. (2023). Acute and sub-chronic toxicity of Liberin, an anti-diabetic polyherbal formulation in rats. *Journal of Ayurveda and Integrative Medicine*, 14(6), 100804.
 12. Thikekar, A. K., Thomas, A. B., Chitlange, S. S., & Bhalchim, V. (2022). Effect of herbal formulation on glimepiride pharmacokinetics and pharmacodynamics in nicotinamide-streptozotocin-induced diabetic rats. *Journal of Ayurveda and Integrative Medicine*, 13(3), 100633.
 13. Upadhyay, R. K. (2021). Antihyperlipidemic and cardioprotective effects of plant natural products: A review. *International Journal of Green Pharmacy (IJGP)*, 15(1).
 14. Vikhe, S., Kunkulol, R., & Raut, D. (2022). Antidiabetic and antihyperlipidemic effects of crude fractions and isolated compound from *Striga orobanchioides* Benth on streptozotocin induced diabetic rats. *Journal of Ayurveda and Integrative Medicine*, 13(3), 100618.
 15. Vikhe, S., Kunkulol, R., & Raut, D. (2022). Antidiabetic and antihyperlipidemic effects of crude fractions and isolated compound from *Striga orobanchioides* Benth on streptozotocin induced diabetic rats. *Journal of Ayurveda and Integrative Medicine*, 13(3), 100618.